A Conservation Evaluation of Smooth Goosefoot, *Chenopodium subglabrum* (Chenopodiaceae), in Canada

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Robson, Diana Bizecki. 2006. A conservation evaluation of the Smooth Goosefoot, *Chenopodium subglabrum* (Chenopodiaceae), in Canada. Canadian Field-Naturalist 120(3): 335–341.

Smooth Goosefoot (*Chenopodium subglabrum*) is restricted to North America and reaches its northern distribution limit in Alberta, Saskatchewan and Manitoba. The habitat of *Chenopodium subglabrum* contains some element of active sand. It is commonly found on the stabilizing edges of active dunes as well as dune blowouts, and occasionally on bare or recently disturbed sand plains. *Chenopodium subglabrum* is a sexually reproducing annual species with seeds that may remain in the seed bank for several years, waiting for the conditions it favours for germination. Germination of this species is erratic, possibly in response to moisture, making the overall population trend difficult to determine. The estimated population in Canada is likely between 5000 and 10000 individuals. There has been considerable loss of habitat as dunes become vegetated. The processes of dune stabilization and fire control threaten survival of this species.

Key Words: *Chenopodium subglabrum*, Smooth Goosefoot, distribution, population size, rare, Alberta, Saskatchewan, Manitoba.

Chenopodium subglabrum (S. Wats.) A. Nels., commonly called Smooth Goosefoot, is a rare, shallow-rooted annual plant (Figure 1) found in the prairie provinces of Canada. Prior to 1990 only small numbers of this species had been observed at 20 sites in Canada (Smith and Bradley 1990*). Search efforts from the mid-1990s on resulted in the discovery of new populations in five Sand Hill regions in Saskatchewan and Manitoba. In 2004, the highest number of individuals ever recorded in Canada was observed, suggesting that this species has a strong temporal component to its rarity. The objective of this paper is to document these recent findings and determine their conservation implications.

Habitat

Chenopodium subglabrum populations occur in the Aspen Parkland, Moist Mixed Grassland, and Mixed Grassland Ecoregions of the Prairie Ecozone (Acton et al. 1998). Within this ecological area, *C. subglabrum* is found in Mixed Grasslands with sandy soils. The populations in Saskatchewan and Alberta are isolated from each other as the land in between them is largely cultivated. The Manitoba populations are particularly isolated, being approximately 500 km from the nearest *C. subglabrum* population in Saskatchewan and about 350 km from the nearest population in North Dakota (Schmoller 2002*). This fragmentation is natural since *C. subglabrum* does not generally grow on the silty and clayey soils that occur in between the various sand hills. The populations that occur along the South Saskatchewan River are less isolated than the ones growing in the sand hills to the south since habitat along the river is largely undisturbed.

Chenopodium subglabrum is an early successional habitat specialist growing typically in the stabilizing

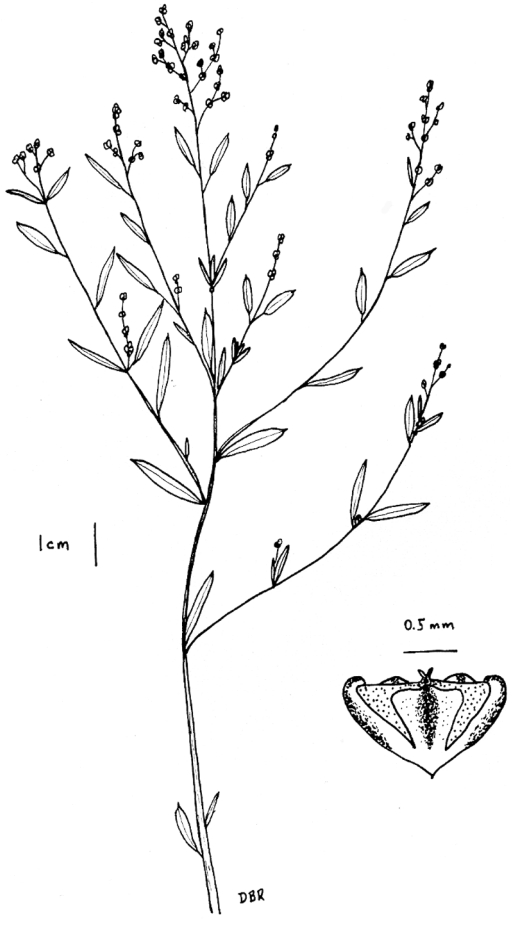

FIGURE 1. Illustration of *Chenopodium subglabrum*. Line drawing by D. B. Robson.

TABLE 1. Nationally and provincially rare plants associated with *Chenopodium subglabrum*.

Province	Sand Hill	Associated Species	
		Nationally rare [1]	Provincially rare [2]
Alberta	Dominion	Nodding Umbrella-plant *(Eriogonum cernuum)* Sand-verbena (*Tripterocalyx micranthus*)	Bur Ragweed (*Ambrosia acanthicarpa*) Annual Skeleton-weed (*Shinnersoseris rostrata*)
Saskatchewan	Dundurn	Hairy Prairie-clover *(Dalea villosa* var. *villosa)* Sand-dune Wheatgrass (*Elymus lanceolatus* ssp. *psammophilus*)	
	Elbow	Western Spiderwort (*Tradescantia occidentalis*)	Sand Nut-sedge (*Cyperus schweinitziii*)
	Great	*Eriogonum cernuum*	*Ambrosia acanthicarpa* Wingless Bugseed *(Corispermum villosum)* *Shinnersoseris rostrata*
	Pelican Lake	*Dalea villosa* var. *villosa*	
	Seward	*Elymus lanceolatus* ssp. *psammophilus*	*Ambrosia acanthicarpa* *Corispermum villosum* *Shinnersoseris rostrata*
Manitoba	Routledge	Sand Bluestem *(Andropogon hallii)* *Tradescantia occidentalis*	Indian Rice-grass (*Achnatherum hymenoides*) *Cyperus schweinitziii* Purple Ball Cactus (*Escobaria vivipara*) Louisiana Broomrape (*Orobanche ludoviciana*) *Shinnersoseris rostrata*
	Brandon (Carberry)	*Dalea villosa* var. *villosa*	Winged Pigweed *(Cycloloma atriplicifolium)* *Achnatherum hymenoides*

1According to Argus and Pryer 1990
2 According to provincial Conservation Data Centres

sand at the edges of active dunes and blowouts, and along eroding, sandy river banks and coulees (Smith and Bradley 1990*; Robson 1997a; Lamont and Gerry 1998*). It is generally found on south- or west-facing actively eroding slopes, at the edge of stabilizing sand and sometimes in dune slacks. Populations tend to occur in discrete units clustered around active dunes and are typically highest in areas of finer and more compacted sand. Given that *C. subglabrum* was found historically along the South Saskatchewan River, it is possible that much of this species' habitat disappeared when Gardiner Dam was built on the South Saskatchewan River in the late 1960s, flooding the sand bars and terraces. Dynamic factors such as grazing, erosion and fire may aid in destabilizing sand, resulting in more habitat for *C. subglabrum* (Robson 1999).

Commonly associated species include the following: Indian Rice-grass (*Achnatherum hymenoides*), Sand Grass (*Calamovilfa longifolia*), Narrow-leaved Goosefoot (*Chenopodium pratericola*), Canada Wild Rye (*Elymus canadensis*), Northern Wheat-grass (*Elymus lanceolatus* ssp. *lanceolatus*), Prairie Sunflower (*Helianthus petiolaris* ssp. *petiolaris*), Hairy Golden-aster (*Heterotheca villosa* var. *villosa*), Skeleton-weed (*Lygodesmia juncea*) and Lance-leaved Psoralea (*Psoralidium lanceolatum*) (Smith and Bradley 1990*; Robson 1997a). Shrub cover often includes: Common Bearberry (*Arctostaphylos uva-ursi*), Hoary Sagebrush (*Artemisia cana* ssp. *cana*), Creeping Juniper (*Juniperus horizontalis*) and Sandbar Willow (*Salix exigua* ssp. *interior*) (Smith and Bradley 1990*; Robson 1997a). *Chenopodium subglabrum* is also associated with six nationally rare and eight provincially rare plants in various locations (Table 1).

Chenopodium subglabrum is an annual plant with bisexual flowers (Clements and Mosyakin 2004). Flowering occurs from June to August and seed production in August and September (Wallis and Wershler 1988). Although no studies on *C. subglabrum* pollination have been performed, other species in this genus are wind- or self-pollinated (Johnson and Ward 1993; Royer and Dickinson, 1999). The distances that *C. subglabrum* pollen travels is unknown. Since the wind-pollinated *C. pratericola* often occurs in the same habitat with *C. subglabrum*, hybridization may be possible, although it has not been observed (Bassett and Crompton 1982).

The fruits and seeds of *C. subglabrum* lack structures that would aid in wind (i.e., hairs) or animal (i.e., burs or fleshy fruits) dispersal although the seeds may ad-

here to wet fur. The seeds likely fall close to the parent plant and may be buried by shifting sand, or travel short distances in the winter over snow crust. This means that the main exchange of genetic material between populations would occur via pollination. Lamont and Gerry (1998*) asserted that dry weather could limit its germination. The dramatic increase in the number of individuals observed at most sites in Saskatchewan in 2004 coupled with the observation that late summer was unusually wet and cool suggests that maximum seed germination occurs under moist conditions. The seeds can likely remain dormant for several years (Robson 1999). This dormancy can last at least eight years; at the Beaver Creek site plants were observed in 1996 and 2004 but not in the years in between. There may be dormant seeds present in stabilized areas that would germinate under appropriate climatic conditions if the area were denuded of its vegetative cover.

No attempts to propagate the species for seed production have been attempted. If seeds were harvested from the wild and grown in a greenhouse the seeds from those plants could be introduced back into the wild. However, given the species' sensitivity to climate conditions, the seeds may not germinate in the wild the following year making assessment of the introduction success difficult to ascertain.

Chenopodium subglabrum is both a halophyte (i.e., salt-loving plant) and a xerophyte (i.e., dry-loving plant) making it a stress-tolerant species (Grime 1979). Plants in the Chenopodiaceae are generally non-mycorrhizal (Mukerji et al. 2000). Since *C. subglabrum* grows in areas of active sand where mycorrhiza are usually not abundant, it is probably normally non-mycorrhizal.

At several sites in Alberta and Saskatchewan there were specimens of *C. subglabrum* that had been grazed. Grazing may have been by cattle or wildlife. Some grazed plants produced side shoots to compensate for stem loss. A report on Ord's Kangaroo Rat (a nationally rare mammal) ecology noted that there were seeds of *C. subglabrum* found in their pouches and food caches so seed predation occurs (Lamont and Gerry 1998*). The growth of several plants observed appeared to be inhibited by an unidentified purplish fungus infecting the leaves.

The Grassland Natural Region is one of the most threatened natural regions in Canada. Over two-thirds of the Mixed Grassland has been lost to cultivation or other development (Wallis 1987). Although some sandy plains have been cultivated, the hilliest areas have not been. The main limiting factors affecting *Chenopodium subglabrum* are its natural narrow preference for unstabilized sites within dune fields and loss of natural habitat through succession. Large areas of once active sand have become stabilized over the last fifty years. The active sand surface of some dunes in the Milk River Sand Dunes of Alberta has been reduced by 50% to 75% over 40 years (Wallis 1987). In the Middle Sand Hills of Alberta, 90% of the sand that was active in 1950 is now stabilized (Wallis 1987). Hugenholtz and Wolfe (2005) estimate that stabilization rates in the Great Sand Hills of Saskatchewan have ranged from 7.2 to 10.5 ha/yr in the northern portion and 1.3-1.4 ha/yr in the southern portion since 1946. Stabilization rates from 1944 to 1996 in the Elbow Sand Hills have ranged from 0.4 to 1.9 ha/yr (Hugenholtz and Wolfe 2005). In the Seward Sand Hills stabilization rates from 1970 to 1991 were estimated to be 1.2 to 3.8 ha/yr (Hugenholtz and Wolfe 2005). The Tunstall Sand Hills stabilization rates from 1969 to 1991 were estimated to be 0.6 to 3.6 ha/yr (Hugenholtz and Wolfe 2005). In Manitoba only one of the six sand hills still has active dunes (Wolfe 2001). The Brandon (Carberry) Sand Hills stabilization rate from 1928 to 1990 has ranged from 1.8 to 17.7 ha/yr (Hugenholtz and Wolfe 2005; Wolfe et al. 2000).

While the exact mechanisms are unclear, a combination of drought conditions and land use appears to be influential in dune stabilization (Hugenholtz and Wolfe 2005; Wolfe et al. 2001, 2002). If current trends continue, rare native plants that now have dangerously low populations could be eliminated entirely. However, Wolfe and Thorpe (2005) speculate that climate change may result in a potential increase in the susceptibility of sand hills to erosion, possibly reversing this stabilization trend.

Exotic invasive weeds are becoming more common in dune areas and have the potential to usurp *C. subglabrum* habitat (Robson 1997a). Exotic plants observed in the same habitats with *C. subglabrum* include: Crested Wheat-grass (*Agropyron cristatum*), Lamb's-quarters (*Chenopodium album*), Leafy Spurge (*Euphorbia esula* var. *esula*), sweet-clover (*Melilotus* spp.) and Russian-thistle (*Salsola tragus*) (Wallis and Wershler 1988; Schmoller 2002*; Robson et al. 2005). Oil and gas exploration and extraction, and to a lesser extent recreation are also potential threats (Wallis 1987; Robson 1997a; Lamont and Gerry 1998*).

Distribution

Chenopodium subglabrum is found in the prairie provinces of Canada, south to Utah and Colorado, west to Washington and Nevada, and east to the Dakotas, Nebraska and Iowa (Figure 2) (Clements and Mosyakin 2004). The populations in Manitoba, Washington, Nevada, Utah, Colorado and Iowa appear to be disjunct from the species' main range (Clements and Mosyakin 2004).

In Alberta there are populations of *C. subglabrum* in five different regions of sand hills: Grassy Lake, Middle, Rolling Hills Lake, Dominion and Pakowki Lake Sand Hills. In Saskatchewan, *C. subglabrum* has been collected in 11 different sand hill regions: Bigstick-Crane Lakes, Birsay, Burstall, Cramersburg, Dundurn, Elbow, Great, Seward, Pelican Lake, Piapot and Tunstall Sand Hills. In southwestern Manitoba *Che-*

nopodium subglabrum populations are found in the Routledge (White and Johnson 1980; Robson et al. 2005) and Brandon (Carberry) Sand Hills.

Due to the annual nature of this species, the population numbers fluctuate widely. Data collected in 2004-2005 supports this hypothesis. At several Saskatchewan locations fewer than 50 individuals were found in the late 1990s but several hundred were observed in 2004. In the Routledge Sand Hills of Manitoba, 19 plants were observed in 2004 but 68 were seen in 2005. Population fluctuations, possibly in response to climate, make it difficult to accurately estimate the number of plants and the vulnerability of populations. In 2004 there were an estimated 8400 plants growing in Canada; in other years only a few hundred to several thousand plants were observed. However, even though plants may not be growing at a site in a given year, seeds are likely present in the seed bank.

The largest populations occur in the Great and Seward Sand Hills of Saskatchewan, and in the Grassy Lake Sand Hills of Alberta. Based on the observed fluctuations in population size and recognition that at any given year there are some *C. subglabrum* seeds dormant in the seed bank, there are likely between 5 000 and 10 000 plants in Canada. The following is an overview of populations in the three provinces of occurrence.

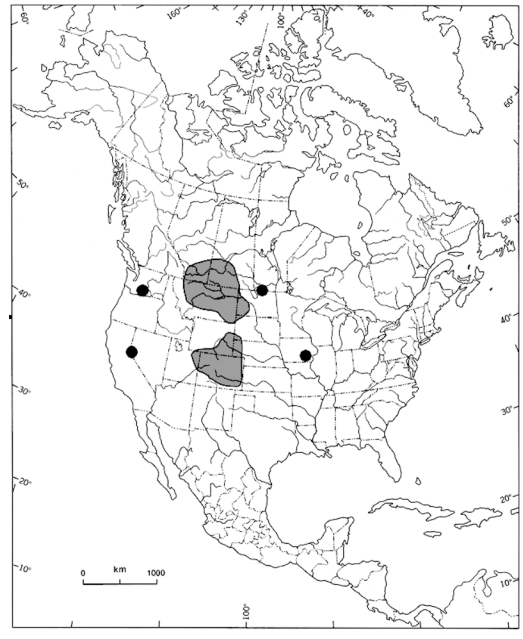

FIGURE 2. Distribution of *Chenopodium subglabrum* in North America.

Alberta

The only Alberta site visited recently (in 2004) was Lost River. Most population research on *C. subglabrum* in Alberta was conducted in the late 1980s (Table 2). Since such a long time has passed since these sites were visited, the dunes may have stabilized further, reducing available habitat.

Saskatchewan

Extensive *C. subglabrum* survey work was done in the mid to late 1990s in the sand hills of Saskatchewan (Robson 1997a; Lamont and Gerry 1998*). Since the first status report was written in 1990 (Smith and Bradley 1990*) new populations have been discovered in the Bigstick-Crane Lakes, Seward, Great and Tunstall Sand Hills (Robson 1997b; Nelson Dynes & Associates 1998*; Lamont and Gerry 1998*) (Table 3). This is balanced somewhat by the apparent loss of five populations where no plants have been observed for at least four decades. The Dundurn, Elbow, Great and Seward Sand Hills locations were visited as recently as 2004.

TABLE 2. Locations and population data for *Chenopodium subglabrum* in Alberta.

Location	Population	Last observation[1]	Population size
Dominion Sand Hills	Lost River	2004	5-50
Grassy Lake Sand Hills	Barnwell	1988	8
	Purple Springs	1988	30
	Turin	1986	100-200
Medicine Lodge Coulee	Medicine Lodge Coulee	1995	?
Middle Sand Hills	Cavendish	1987	?
	Hilda	1988	3
Pakowki Lake Sand Hills	Pakowki Lake North	1980	4
Rolling Hills Lake Sand Hills	Lonesome Lake	1988	1
Estimated size of the population in Alberta [2]			200-300

[1] Data obtained from Smith and Bradley (1990*)
[2] Calculated by adding the minimum number of plants observed or the maximum number of plants estimated at each site and rounding up or down.

TABLE 3. Locations and population data for *Chenopodium subglabrum* in Saskatchewan.

Location	Population	Last observation[1]	Population size
Bigstick-Crane Lakes Sands Hills	Bigstick Sand Hills	1998	21-80
	Crane-Lake Sand Hills	1997	311
	Tompkins	1997	21
Birsay Sand Hills	Dunblane	1961	?
Broderick	Broderick	1989	?
Burstall Sand Hills	Empress	1985	?
	Burstall	1997	202
Cramersburg Sand Hills	Cramersburg	1997	179
Dundurn Sand Hills	Beaver Creek	2004	1-4
	Beaver Creek East	1952	?
	CFB Dundurn	1997	6
Elbow Sand Hills	Bridgeford	1968	?
	Elbow	2004	288-500
	Head of Qu'appelle	1879	?
Great Sand Hills	Sandhill Stockman's Association	2004	2018-3796[2]
	Diamond Ranch	1997	435
	Heck Stockman's Association	2004	18-330[2]
	Signal Stockman's Association	2004	36-330[2]
	Watson's	2004	156 + 330[2]
McMahon	McMahon	1949	?
Pelican Lake Sand Hills	Caron	2002	<10
Piapot Sand Hills	Piapot	1983	?
Patience Lake	Patience Lake	1986	?
Seward Sand Hills	SSH 1	1996	55-540[2]
	SSH 2	2004	39-1000
	SSH 3	2004	13-330
	SSH 4	2001	90-540[2]
	SSH 5	2001	10-540[2]
	SSH 6	2001	2
	SSH 7	2001	1
Tunstall Sand Hills	Bitter Lake	1997	11
Estimated population in Saskatchewan [3]			5000-9700

[1] Data obtained from Harms (1990); Smith and Bradley (1990*); J. & W. Resource Management Consulting (1997*); Robson (1997a); Lamont and Gerry (1998*); Nelson Dynes & Associates (1998*).
[2] Estimated number of plants in 2004; determined by multiplying the number of dune fields present in the area by the average number of plants found at other dunes in the same area.
[3] Calculated by adding the minimum number of plants observed or the maximum number of plants estimated at each site and rounding up or down.

TABLE 4. Locations and population data for *Chenopodium subglabrum* in Manitoba.

Location	Population	Last observation	Population size
Routledge Sand Hills	Routledge	2005	68-75
	Oak Lake	1959	?
Brandon (Carberry) Sand Hills	Spruce Woods	2005	9-25
Estimated size of the population in Manitoba [1]			77-100

[1] Calculated by adding the minimum number of plants observed or the maximum number of plants estimated at each site and rounding up or down.

Manitoba

Although the species was found near Oak Lake in 1959 it was not observed again until 2004 when it was rediscovered (The Manitoba Museum voucher specimen catalogue # 37136) near Routledge (Robson et al. 2005) (Table 4). The active dunes in the Brandon (Carberry) Sand Hills were also searched for *C. subglabrum* in 2004 but no plants were found. However, in 2005 a small population of nine plants (The Manitoba Museum voucher specimen catalogue # 37859) was located. Two plants were found in the same area in 2006. This is the first record ever for this location and represents a range extension for this species of approximately 100 km east.

Evaluation

Significance

Chenopodium subglabrum plays a role in dune stabilization, being one of the few plants that can colonize active sand. Several related species are important economically, including Quinoa (*C. quinoa*), grown for its seeds, and Good King Henry (*C. bonus-henericus*), grown for its leaves (Everett 1981). The aboriginal peoples of the western United States consumed seeds of *Chenopodium pratericola* and Fremont's Goosefoot (*C. fremontii*) (Smith and Bradley 1990*).

Rarity Status

Chenopodium subglabrum was listed by the Committee on the Status of Endangered Wildlife in Canada in 2006 as being a threatened species in Canada. Legal protection of this species via the *Species at Risk Act, 2003* will likely occur in the next few years. This species is considered rare in all three prairie provinces (Packer and Bradley 1984; Maher et al. 1979; White and Johnson 1980) but is not yet protected by any provincial legislation. This species is not protected by any legislation in the United States.

The NatureServe ranks are Global G3G4 (globally vulnerable to apparently secure), Canada N2 (nationally imperiled), Alberta S1 (provincially critically imperiled), Saskatchewan S2 (provincially imperiled), and Manitoba S1 (provincially critically imperiled). The United States ranks are: Montana S1 (critically imperiled in the state), North Dakota S1 (critically imperiled in the state), Nebraska S3 (vulnerable in the state) and Wyoming S3 (vulnerable in the state) (NatureServe 2005*). In the remainder of the states where it occurs it is has either not been ranked (e.g., Colorado, Idaho, Kansas, Nevada, Oregon, South Dakota, Utah and Washington) or is considered unrankable due to a lack of information (e.g. Michigan) (NatureServe 2005*).

Future Outlook

Chenopodium subglabrum is restricted to sandy habitats in the prairie provinces that are geographically isolated from one another. Due to *C. subglabrum*'s annual nature, it experiences large fluctuations in population size from year to year. Dune stabilization has been occurring at a high rate in all of the sand hill habitats where this species occurs. Increased pressure on these ecosystems from the oil and gas industry, and encroachment of exotic weeds further threaten this species.

Acknowledgments

The Canadian Wildlife Service (Environment Canada), Manitoba Conservation, and the Manitoba Museum Foundation Inc., provided funding for this research. Some of the data in this article were obtained from the original status report on this species prepared by Bonnie Smith and Cheryl Bradley. Thanks are extended to the many scientists, particularly Candace Elchuck and Joyce Gould, who provided information for this report, the landowners for allowing access to their land, and Janis Klapecki, Cary Hamel and Cathy Foster for participating in the field surveys.

Documents Cited (marked * in text)

Harms, V. L. 1990. The vascular plant flora of the Beaver Creek Conservation Area, near Saskatoon, Saskatchewan. The W.P. Fraser Herbarium, and the Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.

J. & W. Resource Management Consulting. 1997. Rare plant survey of Dundurn Military Training Reserve, Saskatoon, Saskatchewan.

Lamont, S., and **A. Gerry.** 1998. Species status report *Chenopodium subglabrum* (S. Wats.) A. Nels. Saskatchewan Conservation Data Centre, Regina.

NatureServe. 2005. NatureServe Explorer: An Online Encyclopaedia of Life. Web site: http://www.natureserve.org/explorer. [accessed June 2005].

Nelson Dynes & Associates Inc. 1998. Beverley-Cantuar comprehensive environmental protection plan. Saskatoon, Saskatchewan.

Schmoller, D. 2002. *Chenopodium subglabrum* surveys 2002 field season. Yellowfield Biological Surveys, North Dakota.

Smith, B., and **C. Bradley.** 1990. Status report on the Smooth Goosefoot *Chenopodium subglabrum* (S. Wats.) A. Nels. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 27 pages.

Literature Cited

Acton, D. F., G. A. Padbury, and **C. T. Stushnoff.** 1998. The Ecoregions of Saskatchewan. Canadian Plains Research Center, University of Regina, Regina. 205 pages.

Argus, G. W., and **K. M. Pryer.** 1990. Rare vascular plants in Canada. Canadian Museum of Nature, Ottawa. 274 pages.

Bassett, I. J., and **C. W. Crompton.** 1982. The genus *Chenopodium* in Canada. Canadian Journal of Botany 60: 586-610.

Clements, S. E., and **S. L. Mosyakin.** 2004. Flora of North America Volume 4: Magnoliophyta: Caryophyllidae, Part 1, Chenopodiaceae, Chenopodium. Oxford University Press, Toronto.

Everett, T. H. 1981. Illustrated encyclopedia of horticulture. Volume 3. Garland Publishing Inc., New York.

Grime, J. P. 1979. Plant strategies and vegetation processes. John Wiley & Sons, Toronto.

Hugenholtz, C. H., and **S. A. Wolfe.** 2005. Recent stabilization of active sand dunes on the Canadian prairies and relation to recent climate variations. Geomorphology 68: 131-147.

Johnson, D. L., and **S. M. Ward.** 1993. Quinoa. Pages 219-221 *in* New Crops. *Edited by* J. Janick and J. E. Simon. John Wiley & Sons, New York.

Maher, R. V., G. W. Argus, V. L. Harms, and **J. H. Hudson.** 1979. The rare vascular plants of Saskatchewan. National Museum of Natural Sciences Syllogeus 20. National Museums of Canada, Ottawa. 81 pages.

Mukerji, K. G., B. P. Chamola, and **J. Singh.** 2000. Mycorrhizal biology. Kluwer Academic, New York.

Packer, J. G., and **C. E. Bradley.** 1984. A checklist of the rare vascular plants in Alberta. Provincial Museum of Alberta Natural History Occasional Paper 5. Alberta Culture, Edmonton. 112 pages.

Robson, D. B. 1997a. Ecology of rare vascular plants in southwestern Saskatchewan. M.Sc. dissertation, University of Saskatchewan, Saskatoon, Saskatchewan. 128 pages.

Robson, D. B. 1997b. Smooth Goosefoot discovered in the Webb sandhills. Blue Jay 55: 106-108.

Robson, D. B. 1999. Reasons for prairie plant rarity. Pages 92-95 *in* Proceedings of the Fifth Prairie Conservation and Endangered Species Conference, Saskatoon, Saskatchewan. *Edited by* J. Thorpe, T. A. Steeves, and M. Gollop. Provincial Museum of Alberta, Edmonton.

Robson, D. B., J. Greenall, C. Hamel, and **C. Foster.** 2005. Smooth Goosefoot rediscovered in Manitoba. Blue Jay 63: 81-84.

Royer, F., and **R. Dickinson.** 1999. Weeds of Canada. Lone Pine Publishing, Edmonton.

Wallis, C. A. 1987. Critical, threatened and endangered habitats in Alberta. Pages 49-63 *in* Proceedings of the Workshop on Endangered Species in the Prairie Provinces, Edmonton, Alberta. *Edited by* G. L. Holroyd et al. Provincial Museum of Alberta Natural History Occasional Paper 9.

Wallis, C. A., and **C. Wershler.** 1988. Rare wildlife and plant conservation habitats of southern Alberta. Albert Forestry, Lands and Wildlife; Alberta Recreation and Parks; World Wildlife Fund Canada, Edmonton.

White, D., and **K. Johnson.** 1980. The rare vascular plants of Manitoba. National Museum of Natural Sciences Syllogeus 27. National Museums of Canada, Ottawa. 77 pages.

Wolfe, S. A. 2001. Eolian deposits in the Prairie Provinces of Canada. Natural Resources Canada, Ottawa.

Wolfe, S. A., D. J. Huntley, P. P. David, J. Ollerhead, D. J. Sauchyn, and **G. M. MacDonald.** 2001. Late 18th century drought-induced sand dune activity, Great Sand Hills, Saskatchewan. Canadian Journal of Earth Science 38: 105-117.

Wolfe, S. A., D. R. Muhs, P. P. David, and **J. P. McGeehin.** 2000. Chronology and geochemistry of late Holocene eolian deposits in the Brandon Sand Hills, Manitoba, Canada. Quaternary International 67: 61-74.

Wolfe, S. A., J. Ollerhead, and **O. B. Lian.** 2002. Holocene eolian activity in south-central Saskatchewan and the southern Canadian prairies. Geographie physique et Quaternaire 56 (2-3): 215–227.

Wolfe, S. A., and **J. Thorpe.** 2005. Shifting sands: Climate change impacts on sand hills in the Canadian prairies and implications for land use management. Prairie Forum 30: 123-142.

Received 14 September 2005
Accepted 5 February 2007